

# Valuing the Ecological and Socio-Economic Interests of the Oualidia Lagoon (Morocco): An Ecosystem Services Framework <sup>†</sup>

Nezha Mejjad <sup>1,\*</sup>, Amine el Mahdi Safhi <sup>2</sup>, Abdelmourhit Laissaoui <sup>1</sup>, Samira El Aouidi <sup>1</sup> and Ismail Hilal <sup>1</sup>

<sup>1</sup> National Centre for Nuclear Energy, Science and Technology (CNESTEN), Rabat 10001, Morocco

<sup>2</sup> Department of Building, Civil & Environmental Engineering, Concordia University, 1455 De Maisonneuve Blvd. W., Montreal, QC H3G 1M8, Canada

\* Correspondence: mejjadnezh@gmail.com

<sup>†</sup> Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: <https://asec2023.sciforum.net/>.

**Abstract:** The Oualidia lagoon provides different ecosystem services of socio-economic and ecological interest. These services and goods are important to the local population living there, particularly aquaculture, fishing, and agricultural activities. However, the increase in human activities around such ecosystems has adversely influenced their environmental quality and caused their natural resource depletion. In this context, the main ecosystem services and goods were analyzed; this lagoon provides and defines the main pressures on such an ecosystem. The analysis highlights the need to build a balance between the economic activity growth in this coastal system and the lagoon environment to sustain its natural resource development and avoid their depletion and losses.

**Keywords:** ecosystem services; natural resources; Oualidia lagoon; Morocco



**Citation:** Mejjad, N.; Safhi, A.e.M.; Laissaoui, A.; El Aouidi, S.; Hilal, I. Valuing the Ecological and Socio-Economic Interests of the Oualidia Lagoon (Morocco): An Ecosystem Services Framework. *Eng. Proc.* **2023**, *56*, 77. <https://doi.org/10.3390/ASEC2023-15398>

Academic Editor: Simeone Chianese

Published: 27 October 2023



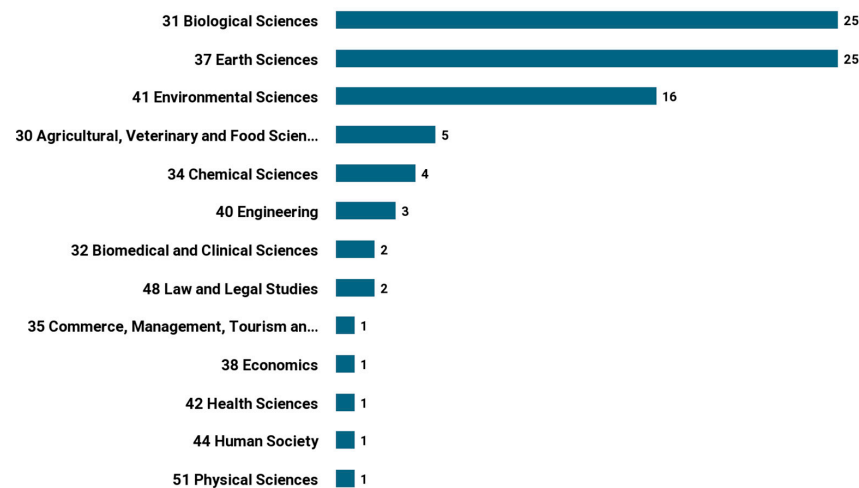
**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

A lagoon is an ecosystem open to the sea that ensures communication between ocean and land. The lagoon ecosystems offer many ecosystem services including habitats, nurseries, fisheries, climate regulation, protection against storms and erosion, and coastal tourism [1].

The Oualidia lagoon is a RAMSAR site as it provides many services and goods that need to be protected and sustained for future generations. Many activities are practiced in and along the lagoon, including oyster farming, which launched in the 1950s, followed by coastal tourism and agriculture.

This lagoon has been the subject of many research works because of its ecological interest and socio-economic importance [2–13]. An in-depth literature search using the Dimensions database revealed that 62 publications were published between 1986 and 2023 focused on biological and earth sciences, ecology, and environmental sciences (Figure 1). This implies that the Oualidia lagoon is suffering from human activity pressures, which the scientific community is aware of. Indeed, several management projects were carried out in the lagoon, mainly to avoid its closure as it is affected by confinement phenomena [2]. In this sense, the present study analyzes the main ecosystem services of the Oualidia lagoon, mainly because almost all previous studies were focused on the monitoring and assessment of pollutants and the lagoon environmental degradation effects on biodiversity.



**Figure 1.** Screenshot of the number of publications in each research category related to our search query, “Oualidia lagoon”. Taken from the Dimensions.ai database on 4 August 2023.

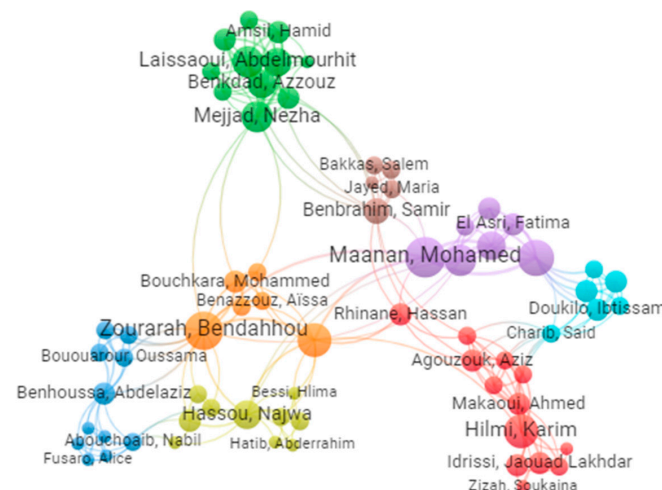
## 2. Methods and Materials

### 2.1. Study Area Description

The Oualidia lagoon is part of the lagoonal complex of the Sidi Moussa-Oualidia lagoon located on the Moroccan Atlantic coastline. This lagoon is located in the region of Abda-Doukkala. Due to its geographical location, the lagoon receives many visitors, mostly in the summer period. Furthermore, the lagoon is known for its biodiversity richness, mainly because it is located in an area affected by upwelling activities, which contribute to the lagoon fisheries’ resource richness including oyster farming. Other activities are practiced in the lagoon, providing income to the local population, including agricultural activities where the lagoon is surrounded by an agricultural area, mainly for vegetables [8].

### 2.2. Data Collection

The data collection was carried out using the Dimensions.ai database, from which we extracted scientific papers related to the “Oualidia lagoon”. The purpose is to define and identify the main research categories and subjects related to the lagoon issue. The search was carried out in titles and abstracts, allowing the collection of 62 scientific research papers. The main authors were Maanan Mo. (10 papers), Zourarah B. (9 papers), Errhif A. (9 papers), followed by Mejjad N. (7 papers) (Figure 2). These research papers are mainly related to environmental assessment and monitoring using different matrices that help in ecosystem service analysis and human pressure analysis.

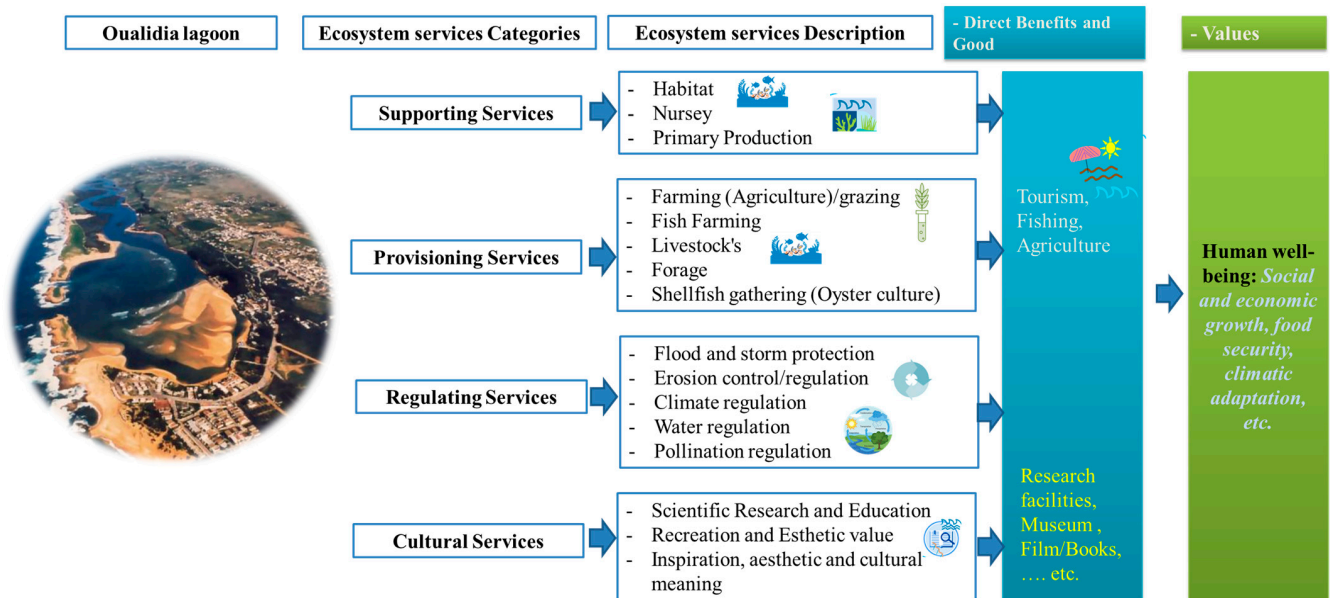


**Figure 2.** Screenshot of co-authorship analysis related to our search, “Oualidia lagoon”.

### 3. Results and Discussion

### 3.1. What Ecosystem Services Does the Oualidia Lagoon Offer?

According to Ma's (2005) conceptual framework, four types of ecosystem services were identified, including supporting services, provisioning services, regulation services, and cultural services Figure 3 [14].



**Figure 3.** The main ecosystem services provided by the Oualidia lagoon.

The Oualidia lagoon presents numerous supporting services that other services rely upon. The Oualidia lagoon plays an essential role as a habitat for many species in addition to being a stopover wintering point for migratory birds. Also, the Oualidia lagoon acts as a natural nursery for juvenile fish [15,16]. The presence of seagrass plants in the lagoon, which are known as the most productive habitats on the earth and act as carbon sinks, is another service the lagoon provides. These plants play an important role as the primary producer of the total productivity of their habitat. It is worth noting that seagrass plays an essential role in climate regulation through sequestering CO<sub>2</sub> [17].

In addition to the lagoon offering what is termed as provisioning services, which include aquaculture and fisheries, these activities are the promoters of other sectors such as coastal tourism and food business. Unless the supporting services are sustainably protected, the lagoon will not be able to provide the provisioning services. Accordingly, human well-being is not only linked to the direct services (provisioning services) but also closely linked to the indirect services (supporting services and regulating services).

Regarding cultural services, the Oualidia lagoon is among the most attractive lagoonal systems in Morocco and in the world as it attracts national and international visitors. Different spiritual and recreational values characterize this lagoon and fascinate its visitors. In addition, the Oualidia lagoon has cultural and historical characteristics distinguishing it from other lagoons. Accordingly, this lagoon was among the most studied and investigated systems, which is another cultural service provided by the lagoon (scientific research and education).

### 3.2. What Pressures Are on the Oualidia Lagoon Ecosystem Services?

The Oualidia lagoon has seen an exponential growth of human activities since the 1950s with the creation of the first oyster farm. Other activities were developed in the lagoon since the 1970s with population growth, mainly agricultural activities, which represent the main income source for the local community. However, this increase in human activities was not well correlated to the environmental growth of the lagoon. Indeed, in

2011, biological contamination by *Salmonella* was detected in farmed and wild bivalve shellfish samples [18]. Consequently, fishing hulls and raising clams were prohibited, which reflects the influences of anthropogenic activities on biodiversity, the lagoon's health, and the local economic activities including coastal tourism and the social sector (job loss). It should be noted that the reported biological contamination is intermittent and not a continuous contamination [3]. An excess of "*Escherichia coli*" in the Oualidia lagoon led to its classification as "Zone B" in 1996 [18]. Bouchriti et al. (1992) [3] reported that oysters harvested from the lagoon contained fecal bacteria and could also contain human pathogens. A study carried out on drinking water and water used for agricultural purposes using water samples collected from the Oualidia region and the lagoon showed that in many wells, the water is not suitable for drinking and agricultural use according to the Moroccan standard NM 03.7.001 [19]. The excessive use of fertilizer, coastal tourism, and farming activities are the possible origin of the water quality degradation. Hassou et al. (2014) [20] indicated that the source of pollution of the Oualidia lagoon has two origins: (i) urban pollution, which is concentrated in the watershed and the downstream part of the lagoon and related to tourism activities; (ii) agricultural activities occupying the upstream part of the lagoon and watershed through the leaching and infiltration of agriculture-related practices around the lagoon, mainly during the rainy season [20].

The analysis showed that there is a lack of microbiological studies carried out in the lagoon in recent years; that the population's incomes depend mainly on the lagoon's natural resources; and that the environmental quality growth of the lagoon does not follow its social and economic growth.

#### 4. Conclusions

The Oualidia lagoon is known as a blue lagoon and the Moroccan oyster capital, which ranks it among the most attractive Moroccan tourist destinations for national and international visitors. Its ecological and socio-economic interests led to extensive investigation of its environmental quality, which resulted in carrying out several management projects to protect it and conserve and safeguard its natural resources from anthropogenic activities.

The analysis of the Oualidia lagoon ecosystem services is still weak regarding the role of the lagoon as a habitat and in climate regulation and greenhouse gas emission mitigation. Developing research projects related to the Oualidia lagoon ecosystem services is an important step toward achieving sustainability in this lagoon.

Seeing the lagoon's importance for the local population, its ecological role as a habitat and nursery, and its role in climate regulation implies developing management projects for regulating human activities in the lagoon instead of focusing on the lagoon itself and only on the assessment and monitoring of the pollution level. Starting from the sources can help build a balance between environmental quality development and socio-economic sector growth.

**Author Contributions:** Conceptualization, N.M.; methodology, N.M.; software, N.M., A.L.; validation, N.M.; investigation, N.M.; resources, N.M.; data curation, N.M., A.e.M.S.; writing—original draft preparation, N.M., A.e.M.S., A.L., S.E.A., I.H.; writing—review and editing, N.M., A.e.M.S., S.E.A., A.L., I.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Data are contained within the article.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Nazneen, S.; Mahmood, G.; Jafar, Z.; Madhav, S. *Ecosystem Services of Lagoon Wetlands System in India*; Wiley: New York, NY, USA, 2021; pp. 111–128. [\[CrossRef\]](#)
2. Bidet, J.C.; Carruesco, C. Étude sédimentologique de la lagune de Oualidia (Maroc). *Oceanol. Acta* **1982**, 29–37.
3. Bouchriti, N.; El Marrakchi, A.; Fahim, A. The microbiological contamination of an oyster growing area in Morocco: The Oualidia lagoon. *Hydroécologie Appliquée* **1992**, 4, 189–202. [\[CrossRef\]](#)
4. Bennouna, A.; Assobhei, O.; Berland, B.; El Attar, J. Étude des populations phytoplanctoniques de la lagune de Oualidia (Maroc); dinoflagellés potentiellement nuisibles. *Mar. Life* **2000**, 10, 3–18.
5. Hilmi, K.; Koutitonsky, V.G.; Orbi, A.; Lakhdar, J.I.; Chagdali, M. Oualidia lagoon, Morocco: An estuary without a river. *Afr. J. Aquat. Sci.* **2005**, 30, 1–10. [\[CrossRef\]](#)
6. Zourarah, B.; Maanan, M.; Carruesco, C.; Aajjane, A.; Mehdi, K.; Freitas, M.C. Fifty-year sedimentary record of heavy metal pollution in the lagoon of Oualidia (Moroccan Atlantic coast). *Estuar. Coast. Shelf Sci.* **2007**, 72, 359–369. [\[CrossRef\]](#)
7. Idardare, Z.; Chiffolleau, J.F.; Moukrim, A.; Alla, A.A.; Auger, D.; Lefrere, L.; Rozuel, E. Metal concentrations in sediment and *Nereis diversicolor* in two Moroccan lagoons: Khnifiss and Oualidia. *Chem. Ecol.* **2008**, 24, 329–340. [\[CrossRef\]](#)
8. Maanan, M.; Ruiz-Fernandez, A.C.; Maanan, M.; Fattal, P.; Zourarah, B.; Sahabi, M. A long-term record of land use change impacts on sediments in Oualidia lagoon, Morocco. *Int. J. Sediment Res.* **2014**, 29, 1–10. [\[CrossRef\]](#)
9. Damsiri, Z.; Natij, L.; Khalil, K.; Loudiki, M.; Richir, J.; El Himer, H.; Elkalay, K. Seasonal characterization of the nutrients state in Oualidia lagoon (Moroccan atlantic coast). *J. Mater. Environ. Sci.* **2017**, 8, 67–77.
10. Mejjad, N.; Laissaoui, A.; El-Hammoumi, O.; Fekri, A.; Amsil, H.; El-Yahyaoui, A.; Benkdad, A. Geochemical, radiometric, and environmental approaches for the assessment of the intensity and chronology of metal contamination in the sediment cores from Oualidia lagoon (Morocco). *Environ. Sci. Pollut. Res.* **2018**, 25, 22872–22888. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Mejjad, N.; Laissaoui, A.; Fekri, A.; Hassen, N.E.H.; Benmhammed, A.; El Hammoumi, O.; Benkdad, A.; Amsil, H. Tracking natural and human impact on sediment dynamics using radiometric approach in Oualidia lagoon (Morocco). *Int. J. Environ. Anal. Chem.* **2022**, 102, 4300–4315. [\[CrossRef\]](#)
12. Mejjad, N.; Laissaoui, A.; Benmhammed, A.; Fekri, A.; El Hammoumi, O.; Benkdad, A.; Amsil, H.; Chakir, E.M. Potential ecological risk assessment of rare earth elements in sediments cores from the Oualidia lagoon, Morocco. *Soil Sediment Contam. Int. J.* **2022**, 31, 941–958. [\[CrossRef\]](#)
13. Mejjad, N.; Laissaoui, A.; El Hammoumi, O.; Fekri, A.; Amsil, H. Geochemical characterization of rare earth elements in sediment profiles from the Oualida lagoon (Morocco). *Acta Geochim.* **2023**, 42, 1051–1064. [\[CrossRef\]](#)
14. Reid, W.V.; Mooney, H.A.; Cropper, A.; Capistrano, D.; Carpenter, S.R.; Chopra, K.; Zurek, M.B. *Ecosystems and Human Well-Being-Synthesis: A Report of the Millennium Ecosystem Assessment*. Millennium Ecosystem Assessment. Island Press. 2005. Available online: <https://www.millenniumassessment.org/documents/document.356.aspx.pdf> (accessed on 15 July 2023).
15. Chaouti, A.; Azirar, A.; Bayed, A. Macrofaunal spatial distribution and community structure in a lagoon without a river discharge (the Oualidia lagoon, NW Morocco). *Mar. Ecol.* **2019**, 40, e12557. [\[CrossRef\]](#)
16. El Asri, F.; Errhif, A.; Tamsouri, M.N.; Martin, D.; Maanan, M.; Zidane, H. Analysis of the structural characteristics and spatial organization of macrobenthic fauna in Oualidia lagoon, Morocco. *Appl. Water Sci.* **2022**, 12, 96. [\[CrossRef\]](#)
17. Deyanova, D.; Gullström, M.; Lyimo, L.D.; Dahl, M.; Hamisi, M.I.; Mtolera, M.S.P.; Björk, M. Contribution of seagrass plants to CO<sub>2</sub> capture in a tropical seagrass meadow under experimental disturbance. *PLoS ONE* **2017**, 12, e0181386. [\[CrossRef\]](#) [\[PubMed\]](#)
18. Chanakya Corporation Environmental Consultant. «Étude pour la Réorganisation et le Développement de la Conchyliculture au Niveau de la Lagune de Oualidia Rapport Phase 3: Études d’impacts sur l’environnement», Rapport Présenté au Département de la Pêche Maritime, Contrat N° 09/CHANAKYA/BG/2008. 2011, pp. 18–20. Available online: <http://fr.scribd.com/doc/58042634/Rapport-EIE-Oualidia-modifie-apres-les-commentaire-08-06-2011> (accessed on 8 August 2023).
19. Alwashali, E.; Jghalef, B.; Fadli, M.; Ashraf, C.; Abdelhak, G. Assessment of microbial contamination of groundwater in Oualidia area, Morocco. *Eur. Sci. J. ESJ* **2014**, 10, 71–84.
20. Hassou, N.; Maanan, M.; Hennani, M.; Zourarah, B.; Assobhei, O. Spatial and temporal variation of faecal pollution indicators (*Escherichia coli* and faecal streptococci) and physico-chemical parameters at the Oualidia lagoon and its watershed (Morocco). *Int. J. Curr. Microbiol. Appl. Sci.* **2014**, 3, 675–694.

**Disclaimer/Publisher’s Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.